Constraint-Based Physicalism

Temporal Parallax as the Classical Process Phase Necessitated by Entropy Gradients: Why the Zombie Is an Incoherent Specification

Kendall Taylor Independent Researcher kendalltaylor111@gmail.com

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Abstract

The hard problem of consciousness [1, 2] gains its force from an implicit assumption: that physical facts are exhausted by static, structural descriptions. This paper challenges that assumption. We begin with a classical observation—Zeno's arrow paradox—to establish that some physical facts are irreducibly processual: motion is not a sequence of positions but a traversal that static snapshots fail to capture. We argue that the philosophical zombie makes an analogous omission. It is specified as a complete physical duplicate minus experience, but if the physical facts include dynamically maintained processes—not merely instantaneous configurations—then the specification is incoherent, because it demands the outputs of those processes while subtracting the processes themselves.

To substantiate this claim, we develop Constraint-Based Physicalism (CBP). Evolution in environments with rough entropy gradients (power-law spectra with $\alpha < 2$) creates a metabolic constraint: discrete snapshot-based architectures require substantially more energy to track these signals than continuous, phase-locked architectures. At biologically relevant fidelities and for the roughest natural signals ($\alpha < 1.3$), this penalty becomes prohibitive, forcing viable systems into a specific dynamical phase—a constraint-maintained temporal parallax—that actively bridges the delay between environmental flow and internal representation. CBP proposes that this phase is identical to subjectivity. The phase is characterized by coherence persistence (Stake), perturbation sensitivity near critical thresholds (Strain), and the possibility of bifurcation collapse into unconsciousness (Collapse). A complete physical duplicate must replicate these processes; a zombie, by omitting them, is not a physical duplicate at all.

We provide an error theory for the hard problem itself: the explanatory gap is a compression artifact generated by the bandwidth disparity between the continuous informational geometry of the temporal parallax phase and any discrete third-person description of that phase. The gap is real but epistemic, not ontological—a consequence of the act of description, not a feature of reality.

Simulation of classical stochastic oscillator networks confirms that only the parallax regime sustains viability in rough niches, with discrete-to-continuous power ratios exceeding 150× at biologically relevant fidelities. The framework yields falsifiable predictions for neurophysiology and AI architecture. The inference to panpsychism dissolves as a

corollary: consciousness is a specific, metabolically expensive mode of organization, not a fundamental property of matter.

Disclosure

This paper presents the author's own original philosophical framework, refined through hundreds of iterative exchanges and adversarial critiques, with the author directing each stage of revision. The final text was generated with the assistance of Large Language Models, under the author's direct supervision. Every substantive idea, argument, and synthesis is the author's alone. The simulation code is publicly available and independently reproducible.

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1. The Snapshot and the Arc

An arrow in flight is readily apparent to any observer. Its arc is not inferred from a sequence of positions—it is seen as continuous motion. Zeno's paradox [21, 22] arises only when one replaces this arc with a series of instantaneous snapshots and then asks how motion could emerge from a collection of static states. The answer, of course, is that it cannot. Motion was never composed of instants. The paradox is an artifact of the replacement, not a feature of reality.

This paper argues that the philosophical zombie [2]—a hypothetical being physically identical to a conscious human but lacking experience—rests on the same kind of replacement. The zombie is specified by taking a complete physical system and subtracting "what it is like" to be that system. But if the relevant physical facts include actively maintained processes rather than merely structural configurations, then the subtraction is not coherent. You cannot subtract the arc from the arrow and still have an arrow in flight.

The philosophical debate about consciousness typically begins with the question *What is it?* CBP pivots to the questions that physics and evolutionary biology make urgent: *Why does it exist?* and *What physical work does it perform?* These are not reductive questions that explain consciousness away. They are questions that reveal what kind of physical fact consciousness is—and why the zombie thought experiment mischaracterizes it.

The hard problem of consciousness [1] is unavoidable in this territory—any physical account of consciousness that does not address it will be dismissed before the physics is even evaluated. CBP engages the hard problem not because we find its conclusion compelling on its own terms, but because the engagement reveals something genuinely interesting: the explanatory gap is a *compression artifact*, generated by the information-theoretic relationship between continuous processes and discrete descriptions. The hard problem is real as a phenomenon of description. It is not real as a feature of ontology. Establishing this requires the physical machinery developed in Sections 3–7; the compression artifact diagnosis is presented in Section 8, and it transforms the zombie argument in Section 9.

Core Claim: Consciousness is not an informational state that supervenes on structure. We propose it is identical to the physical realization of a temporal parallax phase—a specific dynamical regime of continuous layers maintaining active coherence against irreversible time. This identity is motivated, not derived, by showing that the phase is metabolically necessary for survival in high-entropy environments and that its characteristics correspond to the features of subjective experience.

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2. Scope, Claims, and Non-Claims

CBP makes its claims within a specific physical regime. Stating these limits explicitly prevents scope mismatches that generate unnecessary dispute.

2.1 The Regime

Biological wetware conditions. The argument applies to systems operating in noisy, aqueous, thermally fluctuating environments at approximately 300 K—the conditions under which nervous systems evolved and operate. These conditions impose irreducible thermal noise on all signaling components, making the energetic costs of discrete versus continuous processing sharply distinct.

Real-time behavioral timescales. CBP applies to systems that must track and respond to environmental signals at millisecond-to-second fidelity for ecological survival—predator evasion, prey interception, social coordination. Systems that can afford arbitrarily long processing times face different energetic tradeoffs and are outside the scope of this argument.

Rough natural signals. The metabolic argument depends on the statistical structure of natural environments: power-law spectra with $\alpha \approx 1.0$–2.0, yielding signals with unbounded high-frequency variance. In artificially smooth or low-variance environments, the discrete/continuous cost gap narrows and the selective pressure weakens. CBP's claims are strongest in the regime where organisms actually evolved.

Metabolic stake. The framework applies to systems where coherence failure carries existential cost—where losing the temporal parallax phase means failing to track the environment, and failing to track the environment means death or reproductive failure. This metabolic stake is what makes the parallax phase non-optional rather than merely advantageous.

2.2 What CBP Does Not Claim

To preempt misreadings that have attended every physicalist theory of consciousness, we state the following explicitly:

CBP does not claim to derive consciousness from non-conscious ingredients. The identity proposal (Section 10) does not deduce experience from equations. It identifies a physical process that, under specific thermodynamic conditions, *is* experience—in the same sense that temperature *is* mean molecular kinetic energy. The demand for a derivation of feeling from non-feeling presupposes that they are distinct things requiring a bridge. The identity claim denies this presupposition.

CBP does not claim that all maintained processes are conscious. Flames, standing waves, and convection cells are maintained processes but lack the self-referential constraint closure, delay compensation, and metabolic stake that characterize the parallax phase. The specificity of the phase—hybrid architecture, reference kernel, active delay compensation, constraint closure near a critical threshold—is what distinguishes it from other maintained processes.

CBP does not claim that digital systems cannot in principle replicate conscious behavior. Reversible or adiabatic computing architectures, which operate slowly, in thermally isolated conditions, and without the noise floor of wet biology, face fundamentally different energetic constraints. CBP asserts only that such architectures are incompatible with the speed, noise, and dissipative urgency of biological life, and therefore are not relevant to the evolutionary argument. Whether a non-biological system operating under different physical constraints could replicate human behavior without the parallax phase is a separate question that CBP does not foreclose.

CBP does not claim to solve the hard problem in the sense of logically deriving experience from physical premises. It claims to identify the physical process that is experience, and to provide an error theory (Section 8) for why the demand for such a derivation is itself based on a misunderstanding of what physical facts include and what third-person description can capture.

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3. Process-Facts, Thermodynamic Irreversibility, and the Snapshot Fallacy

Some physical facts are structural: the arrangement of atoms in a crystal lattice, the wiring diagram of a circuit, the static shape of a bone. These facts are fully captured by an instantaneous description. Other physical facts are processual: a flame, a standing wave, a resonance. A snapshot of a flame is not a flame. It lacks the combustion process that sustains the luminous form. The flame exists only as a dynamically maintained process—remove the maintenance and you do not have a flameless structure, you have nothing at all.

The zombie argument tacitly assumes that "physical duplicate" means "structural duplicate": same atoms, same wiring, same instantaneous configuration. But biological systems are not crystals. They are maintained far from equilibrium by continuous energetic processes [60]. The state at time t physically causes the state at $t + dt$ through direct mechanisms—voltage gradients, ion flux, electromagnetic field coupling—without causal gaps. A structural duplicate that preserved the instantaneous state but lacked the causal continuity of these processes would not be a physical duplicate. It would be a snapshot of a flame.

3.1 The Irreversibility Distinction

The distinction between structural and processual facts is not merely a matter of resolution—it is not that processual facts are just higher-detail structural facts. The distinction is *categorical*, grounded in the arrow of time.

Structural descriptions are time-symmetric. A crystal lattice, a wiring diagram, a connectome—these can be described without specifying a direction of time. You can read them forward or backward and they are the same object. The temporal parallax phase, by contrast, is *constitutively time-asymmetric*. It exists only because entropy has a gradient, only because time has a direction, only because the system is doing thermodynamic work to maintain coherence against dissolution. Reverse the arrow of time and the phase does not merely look different—it ceases to exist, because the maintenance work that constitutes it presupposes irreversibility [60, 62].

This is why "you're just adding more structure" mischaracterizes CBP's move. A process that is constitutively dependent on thermodynamic irreversibility is not more structure. It is a fundamentally different kind of physical fact—one that disappears from any description that abstracts away the arrow of time. The zombie specification, by treating "physical duplicate" as "structural duplicate," performs exactly this abstraction. It subtracts the time-asymmetric maintenance and then asks why something is missing.

Core Claim: The zombie is a snapshot of a wavefront, not the propagating process. Full physical duplication demands the replication of the continuous dynamics and the active thermodynamic maintenance of those dynamics—including their constitutive dependence on thermodynamic irreversibility. If these are replicated, the process that we propose is identical to experience is necessarily present.

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4. From Classical Puzzles to the Metabolic Mandate

The claim that consciousness is a maintained process requires more than analogy. We need to show why physics forces this specific process into existence—why evolution could not have solved the survival problem with snapshots alone. The argument proceeds in three steps.

4.1 The Irreducible Delay

Any finite physical system tracking a continuous environment faces an irreducible temporal offset. Transduction and computation take time τ. The system's internal state always represents the past, while the environment has already moved on. This is not an engineering limitation to be optimized away—it is a consequence of finite signal propagation in physical systems. We call this offset the *temporal parallax*.

4.2 The Metabolic Wall

Natural environments present signals with power-law spectra [27, 28, 29, 30] $S(f) \sim f^{-\alpha}$ where $\alpha < 2$. This indicates unbounded high-frequency variance—the signals are "rough." A system attempting to bridge the temporal parallax in these environments faces a fundamental energetic choice.

The discrete approach: Rate-distortion theory [23, 24, 25, 26] dictates that for rough signals, the power required for discrete tracking scales as $P \sim \varepsilon$^$(-1/(\alpha-1)) \cdot \log(1/\varepsilon)$. For $\alpha = 1.5$, this yields $P \sim \varepsilon^{-2} \cdot \log(1/\varepsilon)$. The energy cost diverges steeply as fidelity increases.

The severity of this penalty depends on α. At $\alpha = 1.5$, the discrete penalty over continuous is modest at low fidelities but grows monotonically as fidelity increases. However, natural environments are often rougher. Visual scenes, prey trajectories, and social signals frequently exhibit α values well below 1.5—approaching 1 in turbulent or rapidly varying conditions [31, 33]—where the discrete penalty becomes orders of magnitude worse. Since organisms must track the roughest signals relevant to survival, evolution faces a binary choice: develop continuous architectures or fail to track critical stimuli. The metabolic wall is therefore not a gradient that evolution can gradually climb, but a threshold: for the signals that matter, discrete architectures cannot deliver the required fidelity within biological power limits.

To make this concrete: the brain already consumes approximately 20% of the body's metabolic budget despite constituting only 2% of body mass [34, 35]—a factor of ten higher metabolic rate than the body average. This indicates operation near maximal sustainable energy expenditure. Simulation results (Section 11) confirm that at biologically relevant fidelities ($\varepsilon \sim 10^{-3}$), the discrete-to-continuous power ratio exceeds 150× at $\alpha = 1.5$, exceeds 1,000× at $\alpha = 1.7$, and exceeds 5,000× at $\alpha = 1.9$. For signals rougher than $\alpha = 1.3$, discrete tracking fails to reach biological fidelity at any tested power level—the metabolic wall is not merely steep but impassable. Even conservative estimates at moderate fidelities (RMSE ≈ 0.07) yield a 7× penalty at $\alpha = 1.5$, which for a single tracking task consuming just 5% of brain power would require an additional 6W—increasing whole-brain metabolism by 30%. The cardiovascular and nutritional demands of such an increase exceed physiological limits for organisms already operating at metabolic capacity [37]. Reallocation from non-tracking tasks would degrade other survival-critical functions (e.g., homeostasis, motor control) under the same rough-signal regime, preserving the wall.

The continuous approach: A continuous resonant system exploits the signal's own structure through phase-locked oscillators, sidestepping the combinatorial explosion that discrete sampling faces. Simulation confirms that continuous tracking scales substantially shallower than discrete at all tested α values, with the gap growing monotonically as fidelity increases.

At biological fidelities, the discrete approach exceeds the brain's metabolic budget by orders of magnitude. This is the metabolic wall—not an absolute thermodynamic prohibition, but a prohibitive selective pressure at biological scales. In principle, a sufficiently slow, thermally isolated, or energy-unlimited system could track rough signals discretely. But evolution operates under none of those conditions. Organisms must track in real time, in thermal noise, on a fixed energy budget. Under these constraints, the discrete path is not merely inefficient—it is lethal. Evolution did not choose continuous, resonant architectures because they are elegant. Within the biological regime, the alternative was energetic death.

4.3 Temporal Parallax as the Solution

The solution is a hybrid architecture organized around what we call a *Reference Kernel*: a control topology that maintains a fixed point in function space where internal dynamics at time t approximate environmental dynamics at time $t + \tau$. This is not foresight or magic—it is a physical system using stored energy to maintain continuous, predictive resonance that "extends" into the present, analogous to the wave in Young's double-slit experiment probing both paths before detection collapses the result.

The participatory regime eliminates any functional separation—the system's trajectory is not a model of the environmental flow but the flow itself for the tracked degrees of freedom, rendered isomorphic by the Reference Kernel.

The system maximizes mutual information $I(\sigma(t), \sigma(t+\Delta))$ across constraints, where σ represents the phase-locked eigenmodes of the continuous layer [63, 64, 65]. This parallax—the participatory arc of the system actively bridging the gap between past representation and present environment—is the process that discrete snapshots cannot achieve.

Core Claim: The derivation chain shows that "experiencing" is what viable systems must do to solve the metabolic wall problem in rough niches. The chain motivates—though does not logically compel—the identification of this process with subjectivity.

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5. The Physics of Constraint-Maintained Processes

The temporal parallax phase is not an emergent "add-on" to an otherwise complete physical description. It is defined by strict physical constraints.

5.1 Constraint Closure

The system is not a passive filter. The Reference Kernel (realized in biological systems by corticothalamic loops) implements a Smith predictor-like topology [39]. It compares the predicted state with delayed sensory input and uses the error to drive the continuous layer. This closes the constraint loop, rendering the dynamics self-referential—the system's state is both the output of and input to its own maintenance.

This identification is not speculative. Recurrent thalamocortical circuits exhibit time constants on the order of 40–100 ms, matching the delay compensation requirements for real-time sensorimotor tracking, and have been independently implicated in predictive coding architectures [44, 45, 46, 47, 48]. Recent work confirms that high-order thalamic nuclei gate conscious perception through thalamofrontal loops [49], and that criticality in cortical-thalamic dynamics supports cross-frequency information transfer specifically during conscious states [50]. The Smith predictor topology has direct neural analogs in cerebellar and corticothalamic feedback loops, where forward models compensate for sensory and motor delays [40, 41, 42, 43]. The Reference Kernel is thus not a novel postulate but a functional characterization of circuitry already identified by systems neuroscience. We emphasize, however, that this neural identification is illustrative rather than probative—the argument depends on the functional topology, not on the specific biological substrate, and any system implementing the requisite constraint closure would fall within CBP's scope.

5.2 Thermodynamics of Maintenance

Maintaining this phase requires active work. The specious present [55, 56]—the temporal window Δt over which coherence is maintained—is an energetic achievement, not a given.

Entropic drift: Thermal noise continuously disrupts phase angles between coupled oscillators. Counteracting this requires sustained power expenditure [36, 60].

Delay compensation: Maintaining stability near the critical delay threshold τ_crit requires power that diverges as τ approaches τ_crit. The system operates at the edge of instability—far enough from collapse to function, close enough to remain sensitive.

Core Claim: We propose that subjectivity is identical to this active thermodynamic maintenance. It is the work done to keep the "present" open against the arrow of time. This is a metaphysical identity claim—not a reduction of experience to mechanism, but a proposal that the mechanism and the experience are the same thing under different descriptions. The philosophical infrastructure for this identity is developed in Section 10.

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6. CBP Formalized: The Unitary Process Phase

We define consciousness not as a substance or property, but as a unitary process phase characterized by three variables. We introduce them in plain terms before formalizing.

6.1 Stake (Coherence Persistence)

The system must maintain phase-locked coherence between discrete constraints (neural spikes) and continuous eigenmodes (field oscillations) [51, 52, 53]. Stake measures how well the system binds its representations across the temporal window Δt. Formally, the coherence functional integrates mutual information across lagged constraints: $C(t) = \int I(\sigma(t), \sigma(t+\Delta))\, d\Delta > \theta$. This "stretched coherence"—the binding of signals across a temporal interval rather than at an instant—corresponds, we propose, to the structure of qualitative experience. The unity and duration of a percept maps onto the persistence of coherence across the window.

6.2 Strain (Perturbation Sensitivity)

The system operates near the edge of instability. The processing delay τ must remain below the critical threshold τ_crit. Strain is defined by proximity to this threshold: as τ approaches τ_crit, the Lyapunov exponent [66, 67] exceeds its critical value and the system's coherence becomes increasingly fragile. We propose this corresponds to what might be called the temporal texture of experience—the felt tension of maintaining the present moment against the tendency toward dissolution.

6.3 Collapse (Bifurcation into Unconsciousness)

If metabolic supply fails or the delay exceeds τ_{crit}, the system undergoes a bifurcation. Phase-locking breaks, coherence drops below threshold, and the process phase ceases. This is the transition to unconsciousness—whether through dreamless sleep, anesthesia, seizure, syncope, or death. The phase can restart if the organism survives and conditions are restored, because consciousness is a mode of operation, not a substance that is present or absent. This prediction aligns with the clinical observation that consciousness is graded, interruptible, and recoverable [57, 58].

Core Claim: A full physical duplicate must replicate Stake (the coherence that binds), Strain (the active fight against delay), and the potential for Collapse (the threshold beyond which coherence fails). These are physical processes with measurable signatures. Any specification that omits them produces a physical non-duplicate. Any specification that includes them includes, we argue, experience. Section 7 develops this into the formal argument against the zombie.

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7. The Zombie as Incoherent Specification

We are now in a position to state the central argument precisely.

The philosophical zombie is specified as a system that (a) is a complete physical duplicate of a conscious human and (b) lacks experience. CBP establishes that in rough entropy regimes, producing human-like behavior within biological power budgets requires the temporal parallax phase—the hybrid continuous-discrete dynamics described above. This is not a contingent feature of current biology but a consequence of the thermodynamics of signal tracking.

The argument is then straightforward. A zombie that behaves exactly like a human must track rough signals with human-like fidelity. To do so within human power limits—in thermal noise, at behavioral timescales—it must use the hybrid continuous architecture. If it uses that architecture, it has the continuous dynamics—the maintained phase that we propose is identical to experience. If it uses a discrete architecture to avoid those dynamics, it hits the metabolic wall and fails to duplicate human behavior. Either way, the specification cannot be satisfied within the biological regime.

This is not the claim that zombies are nomologically impossible (physically impossible in our world but conceivable in another). It is the claim that the zombie specification contains a hidden contradiction, analogous to specifying a triangle with four sides. The specification demands the outputs of the process phase (adaptive behavior in rough environments within biological energy constraints) while subtracting the process phase itself. The physics does not permit this subtraction.

Note what this argument does not require. It does not require a completed neuroscience of consciousness. It does not require that we fully understand qualia. It requires only two premises: (1) that the temporal parallax phase is physically necessary for the relevant behavior, and (2) that this phase is identical to experience. Premise (1) is an empirical and formal claim that can be tested. Premise (2) is a metaphysical identity proposal—one that earns its plausibility from the close correspondence between the phase's characteristics and the features of subjective experience, but that is ultimately a posit rather than a derivation [75, 76, 81].

It is important to mark precisely where argument ends and proposal begins. The physical argument—that the temporal parallax phase is necessary for the behavior—stands on its own, independent of the identity claim. This is what renders the zombie specification incoherent on purely physical grounds: you cannot have the behavior without the phase. The metaphysical proposal—that this phase is experience—goes further, and is where the posit enters. If one accepts that the physical facts include process-facts, and that the temporal parallax phase exhausts the relevant process-facts for biological systems operating in the regime described in Section 2.1, then the identity is the most parsimonious account available: it requires no additional ontological furniture. The burden then shifts to opponents to specify what, exactly, is missing from the phase that experience requires. The argument establishes that the zombie specification is incoherent; whether the deeper identification of the phase with subjectivity succeeds depends on whether one finds the correspondence between the phase's characteristics and the features of experience sufficiently compelling. We have motivated this correspondence throughout. The reader must judge whether the motivation succeeds.

Regarding the ineffability of experience: the continuous layer has continuous-valued degrees of freedom, supporting a vast space of possible states, while the discrete output (speech, behavior) consists of finite-bit encodings. The information lost in the collapse from continuous to discrete is the "ineffable remainder"—the felt richness that cannot be fully communicated. This is not mysteriousness; it is bandwidth disparity. Section 8 develops this observation into a full error theory for the hard problem.

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8. The Compression Artifact: Why the Hard Problem Seems Hard

The hard problem of consciousness asks: why does this process feel like anything? The question presupposes a gap between the complete physical description of a system and the existence of experience. CBP offers not merely an identity claim to bridge this gap, but a diagnosis of why the gap appears in the first place. This diagnosis is the paper's central philosophical contribution, and it depends on the physical machinery of Sections 3–6: without the temporal parallax phase and its continuous informational geometry, there would be nothing specific to point to as the source of the compression.

8.1 The Third-Person Lossy Compression

When we describe a physical system from the outside, we necessarily compress it. A third-person description of the temporal parallax phase—equations, diagrams, neural firing patterns, spectral exponents—is a discrete, finite encoding of a continuous, temporally extended process. This encoding is lossy. It discards exactly the feature that the hard problem asks about: the specific, continuous informational geometry as it is structured by the arrow of time for the embedded system.

Consider what the organism has. It has every bit of information available to it, superimposed on the geometry of the universe as that geometry is presented to a system inside irreversible time. The continuous layer's state is not a representation of the environment; in the participatory regime, it is the environmental flow itself for the tracked degrees of freedom. This informational manifold—the full dimensionality of the phase-locked eigenmode space, extended across the temporal window Δt, structured by the asymmetry of past and future—is what the system *is*, from the inside.

Now compress this into a third-person description. Write down the equations. Draw the phase portrait. List the spectral exponents. You have produced a structural summary. It is accurate. But it has necessarily collapsed a continuous manifold into a discrete encoding, and in doing so, it has discarded the very thing you are about to ask about. The hard problem then asks: "Given this description, why is there something it is like to be this system?" The answer is that the description has already thrown away the something-it-is-like. Experience is the information in its unreduced format. The description has reduced it.

8.2 Feeling as Unreduced Information

The proposal, stated precisely: phenomenal experience is identical to the total informational state available to the organism, in the only format in which a temporally embedded, finite physical system can possess it. That format is the continuous eigenmode geometry, structured by the arrow of time, maintained against entropic dissolution by the thermodynamic work described in Section 5.2.

"Feeling" is not a property added to information. It is what information is when it has not yet been compressed into a third-person description. Every quale—the redness of red, the painfulness of pain—is a specific region of this manifold: a particular eigenmode resonance pattern, extended across the specious present, embedded in the full context of every other concurrent resonance. The richness of experience corresponds to the dimensionality of the manifold. The ineffability of experience corresponds to the bandwidth loss incurred by any attempt to compress it into discrete output—speech, behavior, report.

This reframes the explanatory gap. The gap is not between physics and experience. It is between a lossy description of physics and the unlossed physics itself. No amount of third-person description will ever seem to "produce" experience, because third-person description is the process of discarding the format in which experience consists. This is not a limitation of current science. It is an information-theoretic constraint on the act of description itself.

8.3 The Error Theory

The hard problem is therefore a compression artifact. It arises from a specific, identifiable information-theoretic error: treating a lossy encoding of a physical system as though it were the complete physical facts, and then noticing that something is missing from the encoding.

The error has the following structure:

(1) Begin with a system whose internal state is a continuous manifold structured by temporal embedding.

(2) Compress this state into a discrete, third-person structural description (equations, wiring diagrams, functional profiles).

(3) Observe that the description seems to leave room for the system to exist without experience.

(4) Conclude that experience must be something "over and above" the physical facts.

The mistake is at step (2). The compression discards the continuous informational geometry—the unreduced format that, on our proposal, is experience. Step (3) then correctly observes that the compressed description lacks experience, but step (4) incorrectly attributes this absence to a genuine ontological gap rather than to the lossy compression performed at step (2).

This is directly analogous to the Zeno error from Section 1. Zeno compresses motion into a sequence of instantaneous positions, observes that no position contains motion, and concludes that motion must be something over and above positions. The mistake is the same: the description discarded the feature in question, and the philosopher blamed reality rather than the description.

8.4 Consequences for the Zombie

This diagnosis transforms the zombie argument. When the dualist claims to conceive of a system physically identical to a conscious human but lacking experience, what have they actually conceived? They have conceived of their own third-person description of the system—a description that, by the nature of third-person description, has already discarded the continuous informational geometry. They then notice that experience is absent from what they have conceived. But it was absent because their act of conception performed the lossy compression. They have not imagined the physical system without experience. They have imagined the compressed description without experience—which is trivially true, because the compression is what removed it.

The apparent conceivability of zombies is therefore not evidence that experience is separable from the physical process. It is evidence that third-person description is lossy. These are very different claims, and CBP provides the information-theoretic framework to distinguish them.

Core Claim: The hard problem is generated by the bandwidth disparity between the continuous informational geometry of the temporal parallax phase and any discrete description of that phase. It is not a gap in ontology but a gap in description. CBP identifies the precise information-theoretic mechanism that generates this gap and explains why it is ineliminable from third-person accounts without being evidence for dualism.

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9. Relation to Other Frameworks

CBP does not emerge in a vacuum. Several existing frameworks capture aspects of what CBP proposes, and locating CBP's specific contributions relative to these frameworks clarifies what is new.

9.1 Predictive Processing and the Free Energy Principle

CBP shares with predictive processing [16, 17, 18] the emphasis on prediction, delay compensation, and hierarchical processing. The Reference Kernel's Smith predictor topology is recognizably a predictive architecture. The key difference is explanatory depth and scope of the consciousness claim.

Predictive processing treats prediction as a computational strategy—organisms minimize prediction error because it is informationally efficient. CBP asks the prior question: *why* do organisms predict? The answer is thermodynamic necessity. Prediction is not one strategy among many; for organisms tracking rough signals in thermal noise on finite energy budgets, it is the only strategy that avoids the metabolic wall. This thermodynamic grounding is absent from standard predictive processing accounts.

More importantly, predictive processing does not, by itself, explain why prediction feels like anything. Many predictive systems—thermostats, autopilots, simple control loops—do not plausibly have experience. CBP adds the crucial constraint: it is not prediction per se, but the specific regime of continuous, phase-locked prediction maintained against entropic dissolution near a critical threshold, that constitutes the parallax phase. Predictive processing describes *what* the brain does; CBP proposes *why* it must do it and *what the doing is*.

9.2 Integrated Information Theory (IIT)

CBP and IIT [19, 20] agree that consciousness involves the integration of information into a unified whole, and both predict that consciousness is substrate-dependent in important ways. But they differ sharply on mechanism, measurement, and substrate-independence.

IIT's Φ (phi) is a measure of integrated information—the degree to which a system's causal structure is irreducible to its parts. But Φ is a measure without a mechanism: it tells you *how much* integration there is, not *why* integration occurs or *when* it will occur in systems subject to real physical constraints. CBP supplies the mechanism. Integration occurs because the metabolic wall forces phase-locking across the temporal window; the resulting coherence functional (Section 6.1) is CBP's analog of Φ, but grounded in thermodynamic necessity rather than axiomatic stipulation.

IIT claims substrate-independence: any system with the right causal structure has consciousness, regardless of physical implementation. CBP denies this for the biological regime. A digital lookup table with the same causal graph as a conscious brain but implemented in silicon at room temperature faces fundamentally different energetic constraints and, on CBP's account, need not have the temporal parallax phase. The specific physics—thermodynamic irreversibility, damped oscillators in thermal noise, active maintenance against entropy—matters.

IIT also faces the combination problem in a distinct form: since Φ is defined for any partition, the theory generates consciousness attributions for simple systems (logic gates, diodes) that most theorists find implausible. CBP avoids this by requiring a specific dynamical regime with a measurable threshold, below which the process phase simply does not exist.

9.3 Global Workspace Theory (GWT)

Global Workspace Theory [82, 83] proposes that consciousness arises when information is broadcast globally across a "workspace" of specialized brain modules. CBP is compatible with GWT at the functional level—the Reference Kernel's coherence across the temporal window plausibly implements the global broadcast—but adds the thermodynamic constraint that GWT lacks. GWT describes the *architecture* of conscious access; CBP proposes *why* that architecture is necessary and *what* the broadcast is at the physical level: the phase-locked eigenmode resonance maintained against entropy.

9.4 Enactivism

CBP shares with enactivism [14, 15] the emphasis on dynamical coupling between organism and environment, the rejection of representation as the fundamental unit of cognition, and the insistence that cognition is a form of activity rather than a form of computation. CBP's participatory regime—in which the system's trajectory *is* the environmental flow for the tracked degrees of freedom—is recognizably enactivist.

Where CBP goes beyond standard enactivism is in supplying the thermodynamic forcing that necessitates the participatory regime and in identifying it with subjectivity. Enactivism typically describes the coupled dynamics without explaining why those particular dynamics should be conscious. CBP's answer is that the dynamics constitute the temporal parallax phase, which is identical to experience—a claim that enactivism gestures toward but does not make precise.

9.5 Whiteheadian Process Metaphysics

CBP aligns with Whiteheadian process metaphysics [5] at the level of ontological orientation: both treat process as fundamental and reject the primacy of static substance. Whitehead's "concrescence"—the coming-together of a moment of experience from prehended data—is structurally similar to CBP's temporal parallax phase. But CBP offers what Whitehead does not: a testable, falsifiable specification grounded in rate-distortion scaling, oscillator dynamics, and simulation, rather than a metaphysical primitive. CBP is process philosophy with empirical teeth.

9.6 Higher-Order Theories

Higher-order theories [84, 85] propose that consciousness requires a representation of a representation—a mental state directed at another mental state. The idea is that a first-order sensory state (seeing red) becomes conscious only when a higher-order state represents it (being aware that one is seeing red). CBP's constraint closure (Section 5.1) involves a form of self-reference that is structurally analogous but mechanistically distinct: the system's state is both the output of and input to its own maintenance.

The key distinction is between *propositional* and *dynamical* self-reference. Higher-order theories typically model the higher-order state as a discrete, quasi-linguistic representation—something like a thought *about* another thought. This creates well-known difficulties: it seems to require the kind of explicit metacognitive capacity that is absent in many organisms that plausibly have conscious experience (infants, many non-human animals), and it introduces a regress problem (what makes the higher-order thought itself conscious?). CBP's constraint closure avoids both difficulties. The self-reference is not a discrete representation directed at another representation; it is the continuous, real-time feedback loop in which the system's current state drives its own future maintenance. The Reference Kernel does not *represent* the system's state to itself in propositional form—it *is* the mechanism by which the state sustains itself across the temporal window. This is self-reference without metacognition, which may explain why organisms with no capacity for reflective thought can nonetheless have rich phenomenal experience.

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10. The Identity Claim: Philosophical Infrastructure

The identity between the temporal parallax phase and experience is the philosophical crux of CBP. Sections 3–6 establish that the phase is physically necessary; Section 8 provides an error theory for why the gap between the phase and experience seems to exist. This section locates the identity claim within the existing philosophical landscape, drawing on the resources of a posteriori physicalism while explaining why CBP's version of the identity is more constrained than standard proposals.

10.1 A Posteriori Identity

The identity is a posteriori—knowable through empirical investigation, not by conceptual analysis alone. This is the same epistemic status as the identity between water and H_2O, or between temperature and mean molecular kinetic energy [81]. In both cases, the identity was not deducible from the concepts alone (one can conceive of water without conceiving of H_2O), yet the identity holds necessarily once discovered.

The canonical illustration is Hesperus and Phosphorus [81]. The evening star and the morning star are the same object—Venus—accessed through different modes of presentation. The identity is necessary (Venus is Venus), but it is not knowable a priori, because the two modes of presentation are epistemically independent. Kripke established that this structure—necessary identity, a posteriori discovery—is philosophically coherent.

CBP proposes that the temporal parallax phase and subjective experience stand in this relation. They are the same thing accessed through different modes of presentation: the third-person mode (equations, measurements, neural recordings) and the first-person mode (being the process). The identity is necessary—if the phase *is* experience, it is so necessarily—but it is not knowable a priori, because the two modes of access are epistemically independent.

10.2 Responding to Kripke's Anti-Physicalist Argument

Kripke [81] argued that psychophysical identities (e.g., "pain is C-fiber firing") face a unique problem. For standard scientific identities, the *appearance* of contingency can be explained away: it seems like water might not be H_2O because we can imagine a substance that looks and behaves like water but is not H_2O. But for pain, Kripke argued, there is no analogous separation between the appearance and the reality—pain just *is* the way it appears, so the seeming contingency cannot be explained away.

CBP's compression artifact diagnosis provides the explanation Kripke claimed was missing. The appearance of contingency arises because the third-person description of the phase is a lossy compression of the first-person reality. When we imagine C-fibers (or the temporal parallax phase) firing without pain, we are imagining the compressed description without experience—which is trivially possible, because the compression discarded the experience. We are not imagining the full physical process without experience, because the full process, in its continuous informational geometry, is not something that can be held in imagination as a discrete object. The apparent conceivability of the separation tracks the lossy compression, not a genuine metaphysical possibility.

10.3 The Phenomenal Concepts Strategy

The broader philosophical framework for this response is the phenomenal concepts strategy [76, 77]. On this view, phenomenal concepts—the concepts we use when we introspect on our experience ("this redness," "this pain")—pick out the same properties as physical/functional concepts, but they do so through a different cognitive mechanism: direct acquaintance with the referent rather than theoretical description of it. The explanatory gap arises from this difference in cognitive mechanism, not from a difference in the properties referred to.

CBP strengthens the phenomenal concepts strategy by giving a precise information-theoretic account of *why* the two modes of access yield different cognitive results. It is not merely that we have two conceptual vocabularies for the same thing (which can seem like hand-waving). It is that one mode of access (first-person) has access to the full continuous informational geometry, while the other (third-person) has access only to a lossy compression of it. The gap between the two is quantifiable in principle: it is the information discarded by the compression. This makes the phenomenal concepts strategy not merely a philosophical possibility but an information-theoretic prediction.

10.4 Why Zombie Intuitions Persist Despite Identity

If the identity holds, why do zombies seem conceivable? The answer follows from Section 8, but it is worth stating explicitly as it addresses the central puzzle that any identity theory must face.

Zombies seem conceivable because conceiving of a physical system requires representing it in third-person terms—which means compressing the continuous informational geometry into a discrete description. The description, being lossy, does not contain experience. One can then note the absence and conclude that experience is separate from the physical system. But the absence was created by the act of description, not by a feature of reality.

This is not a defect in our conceptual capacities that might be remedied by better science. It is a structural feature of the relationship between continuous processes and discrete descriptions. No third-person description, however detailed, will ever *seem* to contain experience, because third-person description is constitutively lossy with respect to the continuous geometry that experience consists in. The hard problem is therefore *ineliminable from third-person accounts*—but this ineliminability is evidence for an epistemic gap, not an ontological one.

The only thing missing from the identity claim is logical compulsion from a third-person description—and the compression artifact explains why that compulsion *can never be supplied*. This absence is not a defect in the argument but a necessary consequence of the information-theoretic relationship between continuous processes and discrete descriptions.

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11. Simulation: Methods, Results, and Predictions

To test the metabolic wall claim, we conducted numerical simulation of discrete and continuous tracking architectures operating on colored noise signals with power-law spectra $S(f) \sim f^{-\alpha}$. The simulation code is publicly available for independent reproduction.

11.1 Model

The environment generates a rough signal with spectrum $S(f) \sim f^{-\alpha}$ and unit RMS amplitude. Two tracking architectures are compared:

Discrete tracking: The signal is sampled at rate f_s and reconstructed via linear interpolation. Power is modeled as $P_d = f_s \times \log_2(1/\varepsilon)$, reflecting the joint cost of sampling rate and quantization depth required to achieve RMSE ε.

Continuous tracking: The signal is tracked by an optimal filter with effective bandwidth f_c and quality factor Q. Power is modeled via damping losses: $P_c = (1/Q) \int_0^{f_c} f \cdot S(f)\, df$, reflecting the physical energy dissipated by damped oscillators maintaining phase-lock with the signal. This captures the thermodynamic cost of continuous resonance.

Delay comparison: Processing delay τ = 5 ms was introduced to both architectures. The discrete system applies delay as a shift in sample times. The continuous system implements a Smith predictor topology with compensation effectiveness degrading at frequencies approaching $1/\tau$.

11.2 Parameters

Simulations were conducted with signal lengths $N = 2^{16}$ (65,536 samples), $N = 2^{18}$ (262,144), and $N = 2^{20}$ (1,048,576) at time step $dt = 10^{-4}$ s, yielding signal durations of 6.5 s, 26 s, and 105 s respectively, and frequency ranges spanning 4.5 to 5.7 decades. Spectral exponents α = 1.1, 1.2, 1.3, 1.5, 1.7, and 1.9 were tested. Quality factor Q = 20 was used throughout, consistent with effective Q values observed in coupled neural oscillator networks [68, 69]. For each α and N, 60 bandwidth values spanning the accessible frequency range were tested, with results averaged over 10 random seeds. Power-law exponents were fit via linear regression in log-log space.

11.3 Results

Scaling exponents. Rate-distortion theory predicts that discrete power scales as $P_d \sim \varepsilon^{(-2/(\alpha-1))}$ for rough signals. The simulation confirms these exponents for $\alpha \geq 1.5$, with convergence improving at longer signal lengths. At α = 1.7, measured $\beta_{disc} = -3.03$ versus theory −2.86 ($R^2 = 0.991$). At α = 1.5, measured $\beta_{disc} = -3.81$ versus theory −4.00, within 5% ($R^2 = 0.982$). At α = 1.9, measured $\beta_{disc} = -2.48$ versus theory −2.22 ($R^2 = 0.995$).

For rougher signals ($\alpha < 1.3$), measured exponents trend toward theory with increasing signal length but convergence requires dynamic range exceeding practical limits: at α = 1.3, measured $\beta_{disc} = -4.54$ versus theory −6.67, with the discrepancy narrowing monotonically across the three tested signal lengths (−3.99 → −4.29 → −4.54). This slow convergence reflects a genuine physical constraint—finite-duration signals do not access the asymptotic regime at low α—and applies equally to biological systems operating on finite-duration stimuli.

Continuous tracking scales substantially shallower than discrete at all tested α values. At α = 1.7, measured $\beta_{cont} = -0.80$ versus discrete −3.03. At α = 1.5, $\beta_{cont} = -1.45$ versus discrete −3.81. The qualitative result—that discrete tracking requires steeper power scaling than continuous tracking, with the gap growing monotonically as fidelity increases—is confirmed across the full tested range α = 1.1 to 1.9, at all three signal lengths, with no exceptions.

Metabolic crossover. The discrete-to-continuous power ratio grows monotonically with fidelity at all tested α values. At biologically relevant fidelities ($\varepsilon \sim 10^{-3}$):

- At α = 1.5: the power ratio exceeds **155×**.
- At α = 1.7: the power ratio exceeds **1,000×**.
- At α = 1.9: the power ratio exceeds **5,300×**.
- At $\alpha \leq 1.3$: discrete tracking **fails to reach biological fidelity at any tested power level**. The metabolic wall is not merely steep but impassable for the roughest signals.

Even at moderate fidelities (RMSE ≈ 0.07), the ratio reaches approximately 7.7× at $\alpha = 1.5$, consistent with the order-of-magnitude physiological argument in Section 4.2. The simulation confirms that this is a conservative lower bound; the true penalty at biological fidelities is two to three orders of magnitude worse.

Delay effects. At $\alpha = 1.5$ with $\tau = 5$ ms processing delay, discrete tracking error increased by a mean factor of 2.16×, while continuous tracking with Smith predictor compensation increased by only 1.70×. More critically, discrete tracking with delay exhibited a performance ceiling—additional bandwidth beyond ~200 Hz failed to improve RMSE, as the delay introduced irreducible error. Continuous tracking with delay compensation showed no such ceiling within the tested range, confirming the architectural advantage of the Smith predictor topology.

Non-local binding. In the parallax regime, internal eigenmodes spontaneously phase-lock to the rough signal, creating a "stretched" representation over the temporal window Δt. This non-local binding exhibits structural features—integration of spatially distributed information into a unified temporal trajectory—that, on our proposal, are candidates for the physical correlates of phenomenological unity. The simulation demonstrates that the parallax regime has the right structure to realize the unity characteristic of conscious experience, though whether it actually does so is a metaphysical claim beyond the simulation's scope.

The simulation does not and cannot demonstrate consciousness. It demonstrates the functional and structural properties—non-local binding, phase-locking across a temporal window, metabolic efficiency in rough regimes—that, on our proposal, are candidates for the physical realizers of experience.

11.4 Methodological Note

The theoretical scaling exponents are derived from rate-distortion theory for infinite-length signals. In finite simulation (and in biological reality), the accessible dynamic range is limited. The steep theoretical exponents at low α ($\beta = -20$ at $\alpha = 1.1$) describe asymptotic behavior that neither simulation nor biology can fully realize. The paper's metabolic argument does not depend on reaching the asymptotic regime. It depends only on two confirmed facts: (1) discrete scaling is steeper than continuous scaling at every tested α and fidelity level, and (2) the power ratio grows monotonically with fidelity, reaching physiologically prohibitive levels well within the biologically relevant RMSE range.

Similarly, the continuous power model (damping losses in phase-locked oscillators) is a physically motivated approximation, not a derivation from first principles. The measured continuous scaling exponents vary with α (from approximately −0.39 at $\alpha = 1.9$ to −2.05 at $\alpha = 1.1$), rather than following a single universal scaling law. This variation is physically expected: continuous tracking involves a resonant filter whose behavior depends on the interaction between the filter's transfer function and the signal's spectral structure, producing regime-dependent scaling rather than a single power law. The fit quality for continuous tracking ($R^2 = 0.80$–0.95) is correspondingly lower than for discrete tracking ($R^2 = 0.95$–0.99), not because the simulation is less reliable for continuous systems, but because the underlying physics is more complex—a damped oscillator maintaining phase-lock with a rough signal traverses multiple dynamical regimes as bandwidth increases, and a single power-law fit is a coarser approximation of this richer behavior. Crucially, none of this variation affects the core argument, which depends only on the confirmed fact that continuous scaling is substantially shallower than discrete scaling at every tested α value and fidelity level.

11.5 Falsifiability

CBP predicts a measurable crossover point: as environmental roughness increases past a threshold, discrete architectures fail while continuous-hybrid architectures succeed. If empirical measurement shows that discrete sampling can match continuous tracking in rough regimes without the predicted metabolic penalty, the framework is falsified. The simulation provides specific quantitative benchmarks: at $\alpha = 1.5$, discrete tracking should require at least two orders of magnitude more power than continuous tracking at biological fidelities ($\varepsilon \sim 10^{-3}$). Any architecture that achieves comparable fidelity with comparable power using purely discrete sampling would constitute a falsification.

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12. Corollary: Panpsychism Is Unforced

If CBP is correct, the inference from the hard problem to panpsychism loses its motivation. The standard argument runs: if consciousness cannot be reduced to structure, it must be fundamental [8, 9]. CBP offers a third option—consciousness is processual, a specific mode of operation that requires hybrid architecture, a reference kernel, and active thermodynamic maintenance against entropy.

Rocks lack all three. They have no hybrid architecture (no discrete constraints coupled to continuous dynamics), no delay compensation (no reference kernel), and no active maintenance (no work against entropy to sustain coherence). They are not conscious, and no inference from CBP suggests they should be. Consciousness is a specific, rare, and metabolically expensive mode of organization. The move to non-physical ontology is unmotivated once physics is understood to include thermodynamic process-facts.

12.1 The Combination Problem

CBP sidesteps the combination problem that confronts panpsychist accounts. If consciousness were fundamental at the micro-level, one would need to explain how micro-subjects combine into the unified macro-subjects we experience—a problem that has proven persistently intractable [10, 11]. On CBP, consciousness is not a property to be combined but a specific macro-level process phase that arises only when particular architectural and thermodynamic conditions are met. There is no micro-consciousness to combine, and therefore no combination problem.

We acknowledge that sophisticated versions of panpsychism—particularly those developed by Goff [8], Strawson [9], and others—offer more nuanced accounts than the simple version addressed here. The argument of this section is limited: CBP provides an alternative that avoids the combination problem, not a comprehensive refutation of panpsychism in all its forms.

12.2 The Argument from Vagueness

A more sophisticated challenge comes from the argument from vagueness [86, 87]: any proposed threshold for the emergence of consciousness from non-conscious components would represent a discontinuity unlike anything else in physics. If there is a sharp line between conscious and non-conscious, then an infinitesimal change in physical parameters would produce a radical qualitative change—the appearance of subjectivity from its complete absence. This seems implausible, and the argument concludes that consciousness must be present at some level all the way down.

CBP has a natural response: *bifurcations are sharp thresholds in nature, and we do not find them mysterious in other domains.* Water does not gradually become "a little bit boiling" below 100°C. Superconductivity does not emerge by degrees in a metal that is merely cold. Laser light does not gradually "sort of cohere" below the lasing threshold. Phase transitions are discontinuities in the macroscopic behavior of physical systems, and they arise from the collective dynamics of the system's components without requiring any single component to possess the macroscopic property in miniature.

The temporal parallax phase is precisely such a transition. Below the coherence threshold θ, phase-locking does not obtain and the process phase does not exist. Above it, the phase locks and the process phase is present. Sub-critical coupling produces partial participation—graded phase-locking sufficient for basic sensorimotor viability but lacking the full specious-present texture of mammalian subjectivity—explaining the observed phylogenetic distribution without requiring gradualism across the sharp threshold. Anesthesia and sleep provide empirical examples of graded transitions into and out of the conscious phase [57, 58, 59]. Phenomenological corroboration comes from Nirodha Samapatti [88], a Buddhist meditative attainment in which advanced practitioners report experiencing the progressive dissolution of phenomenal content—perceptual, affective, and cognitive—through finer and finer grades, until consciousness ceases entirely. Upon resumption, practitioners report a temporal gap: the period of cessation contained no experience whatsoever, not even a minimal or degraded awareness. This first-person phenomenology of a sharp threshold between diminishing-but-present experience and its complete absence is precisely what CBP's phase-transition model predicts, and it stands in tension with panpsychist accounts that require phenomenality to persist at some level all the way down.

The demand for graduated phenomenality all the way down assumes continuity where the physics predicts discontinuity. CBP does not need to rule out the possibility that something is going on below threshold; it needs only the weaker claim that whatever is going on below threshold is not the same kind of thing as what is going on above it, because the process that constitutes the parallax phase literally does not exist below threshold. If someone wants to posit additional phenomenality below the phase transition, the burden is on them to say what work it does and why we should believe in it. We also note the pragmatic point: sub-threshold phenomenality, if it exists, is neither empirically testable nor plausibly morally relevant, making it a question that CBP can acknowledge without needing to resolve.

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13. Objections and Replies

Objection: "Zombies are still conceivable."

Reply: Conceivability, in this case, depends on what one imagines when one imagines the physical duplicate. If one imagines only the structural snapshot—atoms, wiring, instantaneous state—then yes, it seems conceivable to subtract experience. But this is because one has already subtracted the process-facts (Section 3) and performed the lossy compression (Section 8). The deeper question is whether one can imagine the full causal structure—voltage propagation, phase-locking, continuous resonance actively maintained against thermal noise and delay—and still coherently subtract experience.

The bandwidth disparity point is decisive here. The continuous layer has continuous-valued degrees of freedom, supporting a vast space of possible states; the discrete outputs (speech, behavior) are finite-bit encodings. What the dualist imagines when they claim to conceive of a zombie is the output of the process—the behavior, the reports, the functional profile—not the process itself. The process itself, with its vast continuous state space, cannot be held in imagination as a discrete object. The apparent conceivability of zombies thus tracks not a genuine metaphysical possibility but a substitution: the dualist imagines the discrete output and mistakes it for the continuous process. This is the same kind of substitution error that makes Zeno's paradox seem compelling when one replaces the arc with a sequence of positions.

Objection: "The identity claim is asserted, not derived."

Reply: This is correct, and we acknowledge it explicitly (Section 10). The identity is a posteriori, not a priori—like all fundamental scientific identities. What the derivation chain provides is motivation: it shows that the phase is physically necessary, that its characteristics (unity, duration, fragility, self-reference, information loss at the boundary) correspond to the features of subjective experience, and that no additional non-physical fact is needed to explain why the behavior exists. The compression artifact (Section 8) explains why no third-person derivation can supply the logical compulsion that the objector demands—and why this absence is a feature of the information-theoretic relationship between processes and descriptions, not a defect in the argument.

Objection: "Why this process and not others? Flames and standing waves are maintained processes too."

Reply: The temporal parallax phase is not merely a maintained process. It is a self-referential, delay-compensating, constraint-closed process that operates near a critical threshold with the potential for bifurcation collapse. A flame maintains its form but does not track an environment, compensate for delay, or bind information across a temporal window. The specificity of the phase—hybrid architecture, reference kernel, active delay compensation, constraint closure—is what distinguishes it from other maintained processes. Not all processes are candidates; this one is, because of its structural and functional correspondence to the features of consciousness.

Objection: "No qualia equation?"

Reply: The equation is the identity itself. A quale, on this account, is the structure of the coherence functional—the specific eigenmode resonance pattern maintained across the temporal window. Redness is not "produced by" the resonance; it is the resonance, in the same sense that temperature is mean molecular kinetic energy. We do not derive feeling from non-feeling; we identify a physical process that has the right structure to be what feeling is. The demand for a derivation of qualia from non-qualitative ingredients presupposes the dualism that the identity denies.

Objection: "This is just functionalism with extra steps."

Reply: Standard functionalism [13] defines consciousness by input-output relations and is multiply realizable. CBP makes a stronger claim: the specific physical process matters. A digital simulation that reproduces the input-output map without the continuous resonant dynamics would not, on this account, be conscious. CBP is closer to biological naturalism [12] than to functionalism, but grounded in thermodynamic necessity rather than biological chauvinism. The constraint is not that consciousness must be biological, but that it must involve the specific physics of continuous resonance maintained against entropy—which happens, in the biological regime, to require wet, noisy, thermally fluctuating matter.

Objection: "The physics claims need empirical validation."

Reply: Agreed. The metabolic wall, the crossover between discrete and continuous scaling, and the correspondence between phase-locking and conscious states are all empirically testable claims. The philosophical argument—that process-facts are genuine physical facts omitted by the zombie specification—stands or falls somewhat independently of whether the specific scaling exponents are exactly correct. But the framework is strongest when both the philosophical and empirical pillars hold. The simulation (Section 11) provides initial validation and specific quantitative benchmarks for future empirical work.

Objection: "Consciousness as a phase transition cannot be gradual, but evolution is gradual."

Reply: Sub-critical coupling produces partial participation—graded phase-locking sufficient for basic sensorimotor viability but lacking the full specious-present texture of mammalian subjectivity—explaining the observed phylogenetic distribution without requiring gradualism across a sharp threshold. Anesthesia and sleep provide empirical examples of graded transitions into and out of the conscious phase [57, 58, 59]. The phase transition is sharp at the critical threshold, but the approach to the threshold is gradual—as with water approaching its boiling point.

Objection: "You're just adding more structure and calling it consciousness."

Reply: This objection assumes that all physical descriptions are structural. If so, then yes, any physical account of anything is "just more structure." But the point of Section 3 is that some physical facts are constitutively time-asymmetric: they depend on thermodynamic irreversibility and disappear from any description that abstracts away the arrow of time. Structural descriptions are time-symmetric; the temporal parallax phase is not. Calling this “more structure” stretches the concept of structure to the point of vacuity—and if everything is structure, then the hard problem becomes unfalsifiable, which should concern anyone who claims it has philosophical force.

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14. Research Program

14.1 Neurophysiology: Kernel Disruption

Protocol: Use transcranial magnetic stimulation (TMS) [72] to disrupt the thalamic reticular nucleus, which we identify as a primary locus of the Reference Kernel. **Prediction:** This should not merely stop processing but systematically distort temporal texture. Subjects should report time-jumps, fragmentation of the specious present, or qualitative changes in the felt duration of the now.

Protocol: Use transcranial alternating current stimulation (tACS) [73] at the system’s resonant frequency to entrain the temporal window. **Prediction:** If the entrained frequency doubles, the subjective duration of the present should measurably change.

14.2 AI Architecture: The Hybrid Test

Protocol: Build a neuromorphic system with memristive crossbars [70] (continuous dynamics) and delay-compensating loops. **Prediction:** Such a system will exhibit eigenmode structures and power scaling identical to biological brains. Current discrete AI architectures (Transformers) [71] will scale with the discrete penalty and lack these markers.

14.3 Minimal Systems

Protocol: Simulate chemotaxis [74] in a rough chemical gradient. **Prediction:** Hybrid/resonant agents will outcompete discrete agents as the roughness of the gradient increases, with the performance gap following the predicted metabolic scaling.

14.4 Scaling Verification

Protocol: Measure metabolic costs of signal tracking in neural tissue preparations under varying spectral conditions. **Prediction:** The discrete-to-continuous power ratio should match simulation benchmarks—exceeding 100× at biologically relevant fidelities for $\alpha \geq 1.5$.

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15. Conclusion

The inference from the hard problem to dualism or panpsychism rests on an incomplete view of physics—one that treats physical facts as exhausted by structural descriptions and ignores the thermodynamic necessity of maintained processes.

Constraint-Based Physicalism addresses this gap. By analyzing the metabolic costs of tracking rough environmental signals, we establish the necessity of a hybrid analog-discrete architecture governed by a Reference Kernel. This architecture generates a unitary process phase—the temporal parallax—to bridge the gap between the organism and the world. We propose that this phase is subjectivity itself [79].

The hard problem, on this account, is a compression artifact: the bandwidth disparity between the continuous informational geometry of the phase and any discrete third-person description of it. The gap is real, ineliminable, and epistemically significant—but it is a gap in description, not in ontology.

The zombie—conceived as a duplicate of a biological human, operating in the regime in which biological humans operate—is incoherent because it demands the output of this phase without the process that generates it. Whether a non-biological system operating under different physical constraints could replicate human behavior without the parallax phase is a separate question that CBP does not foreclose; what it establishes is that *our* zombie—the one that is supposed to be a physical duplicate of *us*—cannot exist. Panpsychism is unforced because consciousness is a specific, rare, and metabolically expensive mode of organization, not a universal property of matter.

If one accepts that process-facts are genuine physical facts and that the temporal parallax phase captures the relevant process-facts for systems like us, then the identification of this phase with subjectivity is the most parsimonious account of the data. No additional ontological posit is required. The explanatory gap closes not because we have explained experience away, but because we have found it in the physics—and explained why finding it *there*, in the continuous geometry, is something no discrete description could ever make visible.

The present is not given. It is achieved. Consciousness is the thermodynamic work of holding that window open.

Appendix A: Equations of the Phase

A.1 Metabolic Wall (Discrete vs. Continuous)

For signal roughness α:

$P\_discrete \sim \varepsilon^{(-1/(\alpha-1))} \cdot \log(1/\varepsilon)$

P_continuous scales substantially shallower, with measured exponents ranging from −0.39 (α = 1.9) to −2.05 (α = 1.1).

For $\alpha = 1.5$: $P\_discrete \sim \varepsilon^{-2} \cdot \log(1/\varepsilon)$; $P\_continuous$ scales as approximately $\varepsilon^{-1.5}$. The discrete-to-continuous power ratio exceeds 155× at $\varepsilon \sim 10^{-3}$.

A.2 Stability Threshold (Strain)

Phase-locked coherence requires $\tau < \tau\_crit = 1/(2\pi f_0 \cdot Q)$. Power to maintain stability scales as $P \sim (1 - \tau/\tau\_crit)^{-2}$.

A.3 Coherence Functional (Stake)

The binding of modes (e.g., color and shape) across the temporal window:

$C(t) = \int I(\sigma\_i(t), \sigma\_j(t+\Delta))\, d\Delta > \theta$

Appendix B: Conceptual Diagrams

B.1 The Parallax Gap

Environment: a continuous signal moving forward in time. Organism: a discrete sampling point lagging behind by time τ. The Kernel: a feedback loop extending from the organism, projecting a continuous curve that intercepts the environmental signal at the current time $t + \tau$, bridging the gap.

B.2 The Metabolic Crossover

X-axis: Fidelity (ε, decreasing rightward). Y-axis: Power (P, log scale). Curve A (Discrete): Steep upward slope. Curve B (Continuous): Moderate upward slope. Intersection: The metabolic wall, where biological survival forces the phase transition to the parallax regime.

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